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Quantitative measure of feeding potential and the inferred relationship among four agricultural pests (Orthoptera: Acrididae) in India

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Abstract: 【Aim】 Feeding potential of insect pests suggests their ecology and economy and that may direct to extend control measure of them. Can the quantitative order of food consumption during developmental or mature period in different pest species be considered in groups together as closely or diversely related species? To resolve the posed question relative to feeding prototype among different pest species will make possible to dig the solution. 【Methods】 Quantitative measure of food consumption in four Indian agricultural pests of Acrididae, *viz*., *Hieroglyphus banian* (Fab.), *Acrida exaltata* (Walk.), *Spathosternum prasiniferum prasiniferum* (Walk.) and *Oxya fuscovittata* (Mars.) (Orthoptera: Acrididae), were studied. Food consumption per day and total consumption in lifetime for all instars and during lifespan of adults for both sexes of each species were estimated. 【Results】 Within the framework of polyphagous nature and among diverse food sources, only 'the most preferred' host plants were provided to all tests. An identical pattern of consumption rate was noticed among four studied species and it was progressively increased with the advancement of nymphal stages. In all species, females consumed significantly more than males and during adult period all the pests consumed significantly higher than their juvenile days. The amount of consumed food at any nymphal or adult period was notably allied with nymphal or adult period. *A. exaltata* and *S. pr. prasiniferum* were marginally related than the rest two species in terms of lifetime food consumption and mean survival period. The uni- and bivoltine pests (*H. banian* and *A. exaltata*, respectively) were more closely related species than the two related multivoltine pests (*S. pr. prasiniferum* and *O. fuscovittata*) in terms of their lifetime food consumption and mean life survival. 【Conclusion】 Species with longer lifespan, which complete one or two generations per year, are more comparable in feeding potentiality than the short lived species which complete more than two generations per year. An inclusive understanding in this regard may be possible after studying on a number of pest species from different voltine nature.

Key words: Orthoptera; acridid pests; food consumption; lifespan; life survival; host plants

1 INTRODUCTION

The enormous voracity of locusts and their ability to devour absolutely everything they may meet on their wanderings have become proverbial with nearly all people (Uvarov, 1928). Under the scenario of assorted feeding habits of acridids (Orthoptera) on available various food sources, the 'general' and 'daily' behavioural pattern (Uvarov, 1977) of food consumption affect intake quantity and consequently influence the reproductive potentiality of the species. There are two basic principles of the discipline of nutritional ecology. First, the older (and bigger) the insect is, the faster it eats. Indeed, consumption and growth rates increase exponentially with insect age. Second, the older an insect is, the more diversified its diet may become (Howard, 1995).

Feeding habit in relation to refusal or acceptance and intake amount of food in Orthopteran insects depend on several factors such as sex (Nagy, 1952), plant length, leaf position, dial cycle, light intensity, day time, age (Chapman 1957, 1959; Kaufmann 1968), body weight (Gangwere, 1959; Gillon, 1968, 1970; Bernays and Chapman, 1972, 1973) and chemical properties of food (Mehrotra and Rao, 1966). In addition, daily rhythm of feeding also depends on temperature, humidity, rainfall and wind (Goodhue, 1962; Uvarov, 1966). Plant preferences and diet diversity are known to vary among individuals of several polyphagous grasshopper species (Ananthakrishnan *et al*., 1985; Ben Halima *et al*., 1985; Braker, 1986; Howard, 1993, 1995)

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and such variation further depends on 'prior feeding experience' of the individual (Simpson *et al*., 1990; Bernays and Raubenheimer, 1991; Howard and Bernays, 1991; Bernays *et al*., 1992). It was found that males of several species of grasshopper consume more than females (Nagy, 1952; Gangwere, 1959; Louveaux *et al*., 1980) while in some species females consume more than males (Kaufmann, 1965; White and Watson, 1972; White, 1974, 1978). Bailey and Mukerji (1976) demonstrated a relationship between daily food consumption and daily growth of nymphal stages that food consumption amount reached the peak during the first few days of adulthood and decreased thereafter in *Melanoplus bivittatus* (Say.) and in *M. femurrubrum*. On the contrary, a progressive increase of food consumption amount with the advancement of nymphal stages was noticed in several species of grasshoppers, *viz*., *Calliptamus italicus* (Mukhin, 1961), *Schistocerca gregaria* (Lewis and Bernays, 1985), *Melanoplus sanguinipes* (Bomer and Lockwood, 1991) and *Oxya nitudila* (Chand and Muralirangan, 1999). So far literature assorted reveals to a weird representation on consumption pattern in grasshoppers where 'intake amount' neither was restricted to sex specific nor progressively increased from lower to higher nymphal stages.

The studied four species of acridids are polyphagous in nature and considered as agricultural crop pests in India. *Hieroglyphus banian* (Fabricius) is considered as a major pest of paddy, sugarcane and maize in tropical and subtropical countries (Roffey, 1964, 1965; Uvarov, 1966). It is univoltine and prevalently found during September to December; however, in rest of the year they were completely missing in the studied area (Santiniketan, WB). *Acrida exaltata* (Walker) is a pest of cotton (Nayar *et al*., 1976), rice and jute (Bhowmik and Haldar, 1984), bivoltine and abundantly found during May to August and October to January, although in rest of the year they were occasionally present in the studied area. *Spathosternum prasiniferum prasiniferum* (Walker) is reported as a pest of wheat, rice, sorghum and sugarcane (Iqbal and Aziz, 1974). It is multivoltine, found throughout the year but abundant during June to July. *Oxya fuscovittata* (Marschall) is also a multivoltine species, found throughout the year but prevalent during June to July and December to January. It is also reported as a pest of sugarcane, paddy and jute (Hollis, 1971).

Food consumption prototype of a pest suggests its ecology and economy and that may direct to extend its control measure. Under ambient environmental conditions the devouring capacity, specially the amount of ingested food of a pest emphasizes its potentiality of higher mating frequencies, repeated oviposition rate and higher fecundity followed by substantial outbreak of the species. Food consumption pattern of the studied four pests is noteworthy at this point that how much food can be ingested by a pest daily or in its life time when the particular pest is allowed to fed its 'most preferred food plant'? Is the consumption quantity increased gradually from early to late instar stages uninterruptedly or it is a phenomenon of sporadic event? And on the basis of quantitative order of food consumption, can the species be grouped together as closely or diversely related species? Under the scenario of the above hypotheses the present investigation was done on the four agricultural pests of Acrididae found in and around Santiniketan, West Bengal, India.

2 MATERIALS AND METHODS

2.1 Test insects and food preparation

2.1.1 Test insects: The tested four species of acridids were *H. banian*, *A. exaltata*, *S. pr. prasiniferum* and *O. fuscovittata*. All the species were collected by hand sweeping with an insect net of 2 ft diameter from the agricultural fields of Santiniketan, WB, India (23.68°N, 87.68°E). The field species were separated by hand and transferred to the laboratory insect cages. One nylon-gauged insect cage (4 ft × 2.5 ft × 3 ft) was dedicated for one species only irrespective of sex and individual number. Time to time collected individuals of the same species from wild were poured into a cage which is dedicated to that species. Food-plant sets with nearly equal amount of *Cynodon dactylon* Pers. (Poaceae) and *Cyperus kyllingia* Endl. (Cyperaceae) were provided in water filled (300 mL) beakers to all the species during rearing. On the floor of the cage four numbers of sterilized wet-sand filled porcelain trays (12 in × 8 in × 4 in) were provided for oviposition. Few drops of water were added daily to keep the sand moist. The cages were kept under natural environmental condition with adequate aeration and illumination. The species were allowed to mate in the cage and females oviposited eggs (in egg-pod) into the sand. At regular intervals egg pods were collected from sand by a hand mesh. The collected egg pods of a particular species were then transferred to sterilized wet-sand filled plastic cups

(300 mL) covered by mosquito-net and placed in environmental chamber under 36 ± 2℃ and 70% ± 5% RH. In a cup not more than 4 egg pods were provided. Once the hatchlings were emerged out from sand they were transferred to the nymphal rearing plastic jars (3 L in capacity) by soft cotton balls.

2.1.2 Food preparation: Fresh green leaves of *C. dactylon* and *C. kyllingia* were taken in equal amount [10 g *C. dactylon* and 10 g *C. kyllingis* with a total amount of 20 g (wet weight)] to prepare mixed diet (dietary unit) for each species. The selection of plants on mixed diet was based on our previous investigation where we recorded these plant species were their 'most preferred' food under laboratory condition (Das *et al.*, 2001, 2008). Clipped fresh leaves were placed in a 100 mL water filled conical flasks. Along with dietary units for experimental purpose a similar 'control dietary unit' was also prepared.

2.2 Feeding and food consumption experiments

In a three litre capacity transparent plastic jar one 'dietary unit' was placed in the middle on the floor of the jar. The floor of each jar was covered with tissue paper and a few drops of water were sprayed regularly to keep the paper moist. The mouth of each jar was covered with nylon gauge to pass fresh air. Twenty nymphs of *H. banian* (1st instar, 24 h starved) were taken from our laboratory maintained rearing stock and were placed in a jar. Three such replicates for the 1st instar nymphs of *H. banian* (n = 20 × 3 = total 60) were prepared. In this way experimental jars for rest of the nymphal stages of *H. banian* were made (2nd instar, n = 20 × 3 = 60; 3rd instar, n = 20 × 3 = 60; 4th instar, n = 20 × 3 = 60; 5th instar, n = 20 × 3 = 60; 6th instar, n = 20 × 3 = 60). Likewise, three 'nymphal sets' for rest of the each three species were also prepared from our laboratory maintained rearing stocks. In addition, like 'nymphal set', sex-wise 'adult sets' were also prepared for four species each. Only those adult individuals (0-day fledging adult) were considered for experiment who reached to adulthood either in experimental 'nymphal sets' or in our mother stock. Twenty adult males were placed in an earlier designed transparent plastic jar (3 L in capacity). Three replicates of each jar were prepared for males only for a species (male adult set, n = 20 × 3 = 60). Likewise, female 'adult sets' (n = 20 × 3 = 60) were also prepared. Both male and female sets were prepared for each of the four species. In adult jars 100 g mixed diet was provided in each jar as their food [50 g *C. dactylon* and 50 g *C. kyllingia* with a total amount of 100 g mixed diet (wet weight)]. All adults used for experiment were starved for 24 h and were almost of the same age group. All individuals were allowed to fed the mixed plant for 24 h under natural photoperiodic condition (12L∶12D), temperature (24 – 30℃) and relative humidity (65% – 75%).

To minimize errors of plant weight either consumed or not, due to evaporation of water through leaves, plants used in 'control set' as well as in 'experimental sets' were dried at 60℃ for 48 h using an electro-digital micro-oven. The dry weight of the control diet (unconsumed) was considered as total provided food (W_S). Water content (%) of the experimental diet was calculated by the equation, water content (%) = (wet weight – dry weight) / wet weight × 100%. On consumption during total period (days) of respective instar stage of a particular species food plants along with its cut and dropped leaflets were collected from respective jars and also dried at 60℃ for 48 h. For example, mean food consumption period of the 1st instar nymphs of *H. banian* was 13.5 days, the 2nd instar = 12.8 days, the 3rd instar = 14.8 days, the 4th instar = 17.5 days, the 5th instar = 19.8 days and the 6th instar = 15 days (see Table 1 for other species). We allowed to feed all nymphs of a particular instar (n = 60) during their respective lifespan continuously. During this test we have replaced food plants (old cut twigs) twice with an interval of 4 to 5 days by fresh clipped twigs due to either the old twigs became pale and dry or they exhausted almost. Whenever we replaced the diet, we preserved old cut twigs along with cut leaf-droplets for calculation of food consumption amount. The dried residual unconsumed food plants were weighted to get its dry weight (W_R). By deducting dry weight of residual unconsumed foods (W_R) from dry weight of control food (W_S), the amount of consumed food (dry weight) (W_C) was calculated by the equation, $W_C = W_S - W_R$. Based on water content (%) in plant, the dried consumed food (W_C) was then converted into its fresh live amount. From total consumed food amount (wet weight) by 20 nymphs/day (this number was taken in each jar), the food consumption/day/individual was calculated.

Instar wise food consumption was recorded throughout the instar lifespan because of disparity of food consumption per day during the life span of an instar stage. Due to this anomaly, to calculate the mean food consumption/day/individual of a particular instar, the total amount of consumed food by a particular instar was divided by the life span period (days) of that particular instar. In this way, food

consumption/day/individual was calculated at each instar stage (1st to 6th) to each species. On the other hand, for calculation of adult food consumption (male and female, separately), continuous day to day data were taken from fledgling stage to its death. Like nymphal stages, the mean food consumption/day/individual was also calculated for each species in each sex. By multiplying the mean life span (days) of adult of a species to the mean food consumption/day/individual, the total amount of food consumption/adult in its lifetime was calculated. For both adult sexes food consumption/day/individual and food consumption/lifetime/individual were recorded separately. During the experiment the lifespans of each instar and adults were recorded separately. All weights were taken using Metlar PB.

2.3 Data analysis

All data and interpretation were analysed using MS Excel. The statistical analysis of regression equation between mean lifespan and mean lifespan food consumption of each species and the preparation of dendrogram was done by using SPSS software (v. 11.5).

3 RESULTS

3.1 Food consumption during nymphal period (the 1st to 6th instar stages)

3.1.1 *H. banian*: It was recorded that per day food consumption of individual hoppers of *H. banian* was 3.93 mg (1st instar), 34.06 mg (2nd instar), 92.37 mg (3rd instar), 297.67 mg (4th instar), 629.79 mg (5th instar) and 1 014.08 mg (6th instar). During life span of each instar period it consumed 53.05 mg (1st instar, per day mean consumption = 3.93 mg × mean life span of 1st instar hopper = 13.5 days), 435.96 mg (2nd instar, 34.06 × 12.8), 1 367.07 mg (3rd instar, 92.37 × 14.8), 5 209.22 mg (4th instar, 297.67 × 17.5), 12 469.84 mg (5th instar, 629.79 × 19.8) and 15 211.2 mg (6th instar, 1 014.08 × 15). Throughout the nymphal period of 93.4 days (1st to 6th instar) in *H. banian*, total amount of 34 746.34 mg food was consumed (Table 1).

3.1.2 *A. exaltata*: Hoppers of *A. exaltata* consumed a mean amount of 3.7 mg (1st instar), 22.75 mg (2nd instar), 77.91 mg (3rd instar), 212.82 mg (4th instar), 501.32 mg (5th instar) and 928.76 mg (6th instar) food per day per individual. During lifespan of each instar stage it consumed 46.25 mg (1st instar, per day mean consumption = 3.7 mg × mean life span of 1st instar hopper = 12.5 days), 222.95 mg (2nd instar, 22.75 × 9.8), 973.87 mg (3rd instar, 77.91 × 12.5), 2 936.91 mg (4th instar, 212.82 × 13.8), 8 271.78 mg (5th instar, 501.32 × 16.5) and 11 145.12 mg (6th instar, 928.76 × 12). Throughout the nymphal period of 77.10 days (1st to 6th instar) in *A. exaltata*, a total amount of 23 596.88 mg food was consumed (Table 1).

3.1.3 *S. pr. prasiniferum*: Per day food consumption of individual hopper of *S. pr. prasiniferum* was 2.83 mg (1st instar), 8.21 mg (2nd instar), 25.55 mg (3rd instar), 89.76 mg (4th instar), 239.63 mg (5th instar) and 621.36 mg (6th instar). During life span of each instar period it consumed 27.73 mg (1st instar, per day mean consumption = 2.83 mg × mean life span of 1st instar hopper = 9.8 days), 68.14 mg (2nd instar, 8.21 × 8.3), 250.39 mg (3rd instar, 25.55 × 9.8), 1 077.12 mg (4th instar, 89.76 × 12), 2 635.93 mg (5th instar, 239.63 × 11) and 7 145.64 mg (6th instar, 621.36 × 11.5). In its nymphal period of 62.4 days (1st to 6th instar), 11 204.95 mg of food was consumed (Table 1).

Table 1 Food consumption amount (per day and nymphal tenure) during developmental period of four acridids

Species name		Developmental stage (instar)						
		1st	2nd	3rd	4tb	5th	6th	Total (1st to 6th)
H. banian	Mean lifespan (d)	13.5 ±1.0	12.8 ±1.5	14.8 ±1.5	17.5 ±1.8	19.8 ±1.8	15.0 ±1.5	93.40 ±1.5
	Mean food consumption (mg/day/individual)	3.93 ±0.5	34.06 ±4.5	92.37 ±5.1	297.67 ±7.2	629.79 ±8.3	1 014.08 ±8.7	
	Mean food consumption (mg/lifespan/individual) *	53.05 ±0.5	435.96 ±6.7	1 367.07 ±7.65	5 209.22 ±7.9	12 469.84 ±8.2	15 211.20 ±8.5	34 746.34 ±6.57
A. exaltata	Mean lifespan (d)	12.5 ±1.0	9.8 ±1.0	12.5 ±1.1	13.8 ±1.3	16.5 ±1.5	12.0 ±1.2	77.10 ±1.2
	Mean food consumption (mg/day/individual)	3.70 ±0.5	22.75 ±3.2	77.91 ±2.5	212.82 ±5.6	501.32 ±6.7	928.76 ±7.2	
	Mean food consumption (mg/lifespan/individual) *	46.25 ±1.0	222.95 ±2.2	973.87 ±4.9	2 936.91 ±5.2	8 271.78 ±6.8	11 145.12 ±8.0	23 596.88 ±4.68
S. pr. prasiniferum	Mean lifespan (d)	9.8 ±1.0	8.3 ±1.0	9.8 ±1.5	12.0 ±1.5	11.0 ±1.8	11.5 ±1.5	62.4 ±1.4
	Mean food consumption (mg/day/individual)	2.83 ±0.5	8.21 ±2.2	25.55 ±3.2	89.76 ±2.2	239.63 ±4.6	621.36 ±6.2	
	Mean food consumption (mg/lifespan/individual) *	27.73 ±0.5	68.14 ±0.8	250.39 ±1.3	1 077.12 ±3.3	2 635.93 ±4.8	7 145.64 ±5.5	11 204.95 ±2.7
O. fuscovittata	Mean lifespan (d)	12.8 ±1.0	8.8 ±0.5	10.5 ±1.0	14.8 ±1.3	12.3 ±1.2	15.5 ±1.5	74.7 ±1.1
	Mean food consumption (mg/day/individual)	3.54 ±0.5	10.25 ±1.2	30.61 ±2.6	112.46 ±2.8	424.39 ±3.6	732.52 ±6.8	
	Mean food consumption (mg/lifespan/individual) *	45.31 ±1.2	90.20 ±2.6	321.40 ±4.5	1 664.40 ±5.1	5 219.99 ±6.4	11 354.06 ±7.6	18 695.36 ±4.6

* Mean food consumption (g/lifespan/individual) = mean food consumption (mg/day/individual) multiplied with Mean lifespan (d) of the instar. All data were recorded as mean ± *SD*. Occasionally *H. banian* and *A. exaltata* passed through an additional instar stage (7th) than the rest of the species. We ignored those data where individuals showed additional instar stage (7th) and considered only those individuals who had up to 6th instar stage.

3.1.4 *O. fuscovittata*: Per day food consumption of individual hopper of *O. fuscovittata* was 3.54 mg (1st instar), 10.25 mg (2nd instar), 30.61 mg (3rd instar), 112.46 mg (4th instar), 424.39 mg (5th instar) and 732.52 mg (6th instar). During life span of each instar period it consumed 45.31 mg (1st instar, per day mean consumption = 3.54 mg × mean life span of 1st instar hopper = 12.8 days), 90.20 mg (2nd instar, 10.25 × 8.8), 321.40 mg (3rd instar, 30.61 × 10.5), 1 664.40 mg (4th instar, 112.46 × 14.8), 5 219.99 mg (5th instar, 424.39 × 12.3) and 11 354.06 mg (6th instar, 732.52 × 15.5). In its nymphal period of 74.7 days (1st to 6th instar) *O. fuscovittata* consumed a total amount of 18 695.36 mg food (Table 1).

3.2 Food consumption during adult period

3.2.1 *H. banian*: The mean life spans of adult male and female individuals of *H. banian* were 27.5 days and 41.5 days, respectively. It was recorded that adult male and female of *H. banian* consumed 1 225.46 mg and 1 456.23 mg food per day per individual, respectively. In adult lifespan, an individual of male and female consumed 33 700.15 mg and 60 433.54 mg food, respectively. Thus during lifetime of *H. banian* of 120.9 days (nymphal mean period = 93.4 days + adult male mean life span = 27.5 days), one male individual consumed 68 446.49 mg (34 746.34 + 33 700.15) and one female individual in its total mean lifetime of 134.9 days (93.4 + 41.5) consumed 95 179.88 mg (34 746.34 + 60 433) of food (Table 2).

3.2.2 *A. exaltata*: The mean life spans of adult male and female individuals of *A. exaltata* were 31 days and 42 days, respectively. Each adult male and female consumed 1 188.63 mg and 1 452.6 mg of food per day, respectively. During life span of adult an individual male and female consumed 36 847.53 mg and 61 009.2 mg food, respectively. Thus during lifetime of *A. exaltata* of 108.1 days (nymphal period = 77.1 days + adult male mean life span = 31 days), one male individual consumed 60 444.41 mg (23 596.88 + 36 847.53) and one female individual in its mean lifetime of 119.1 days (77.1 + 42.0) consumed 84 606.08 mg (23 596.88 + 61 009.20) of food (Table 2).

3.2.3 *S. pr. prasiniferum*: Adult male and female of *S. pr. prasiniferum* consumed 727.67 mg and 820.5 mg food per day per individual, respectively. In lifespan of adult male (23.5 days) and female (36.5 days), an individual male and female consumed 17 100.24 mg and 29 948.25 mg food, respectively. Thus during male lifetime of *S. pr. prasiniferum* of 85.9 days (nymphal mean period = 62.4 days + adult male mean life span = 23.5 days), one male individual consumed 28 305.19 mg (11 204.95 + 17 100.24) and one female individual in its mean lifetime of 98.9 days (62.4 + 36.5) consumed 41 153.20 mg (11 204.95 + 29 948.25) of food (Table 2).

3.2.4 *O. fuscovittata*: Adult male and female of *O. fuscovittata* consumed 908.37 mg and 968.37 mg food per day per individual, respectively. In lifespan of adult male (26.5 days) and female (37.5 days), an individual male and female consumed 24 071.80 mg and 36 313.87 mg food, respectively. Thus during male lifetime of *O. fuscovittata* of 101.2 days (nymphal mean period = 74.7 days + adult male mean life span = 26.5 days), one male individual consumed 42 767.16 mg (18 695.36 + 24 071.80) and one female individual in its mean lifetime of 112.2 days (74.7 + 37.5) consumed 55 009.23 mg (18 695.36 + 36 313.87) of food (Table 2).

Table 2 Life span and food consumption amount during developmental period, adult period and in lifetime among four acridids

Species name		Developmental stage (DS) (1st to 6th instar)	Adult stage (AS)		Lifetime (DS + AS)	
			Male	Female	Male	Female
H. banian	Mean lifespan (d)	93.40 ± 1.5	27.5 ± 2.2	41.5 ± 2.3	120.9 ± 1.85	134.9 ± 1.87
	Mean food consumption (mg/day/individual)		1 225.46 ± 9.2	1 456.23 ± 9.8		
	Mean food consumption (mg/lifespan/individual)*	34 746.34 ± 6.57	33 700.15 ± 9.1	60 433.54 ± 9.5	68 446.49 ± 7.83	95 179.88 ± 8.03
A. exaltata	Mean lifespan (d)	77.10 ± 1.2	31.0 ± 1.9	42.0 ± 2.0	108.1 ± 1.55	119.1 ± 1.61
	Mean food consumption (mg/day/individual)		1 188.63 ± 8.5	1 452.6 ± 9.5		
	Mean food consumption (mg/lifespan/individual)*	23 596.88 ± 4.68	36 847.53 ± 9.2	61 009.20 ± 9.8	60 444.41 ± 6.94	84 606.08 ± 7.24
S. pr. prasiniferum	Mean lifespan (d)	62.4 ± 1.4	23.5 ± 2.2	36.5 ± 2.3	85.9 ± 1.81	98.9 ± 1.89
	Mean food consumption (mg/day/individual)		727.67 ± 7.2	820.5 ± 8.3		
	Mean food consumption (mg/lifespan/individual)*	11 204.95 ± 2.7	17 100.24 ± 6.8	29 948.25 ± 7.6	28 305.19 ± 4.75	41 153.2 ± 5.15
O. fuscovittata	Mean lifespan (d)	74.7 ± 1.1	26.5 ± 1.9	37.5 ± 2.6	101.2 ± 1.5	112.2 ± 1.85
	Mean food consumption (mg/day/individual)		908.37 ± 8.5	968.37 ± 9.6		
	Mean food consumption (mg/lifespan/individual)*	18 695.36 ± 4.6	24 071.80 ± 8.5	36 313.87 ± 9.2	42 767.16 ± 6.55	55 009.23 ± 6.90

DS is the sum of all instars' lifespan; lifetime is the sum of DS and AS. * Lifespan food consumption of DS is the summation of all instars' food consumption. Lifetime food consumption is the cumulating amount of DS and AS of respective sex.

4 DISCUSSIONS

In nymphal developmental period from the 1st to 6th instar stages, all the four pests showed comparable behavioral pattern of food consumption rate. It was observed that food consumption rate (mg/instar/individual) progressively increased from early to late instar nymphal stages. The consumption rate 'trend-line' on exponential scale through all instar nymphal stages in each species was significantly different enough from early to late stages (Fig. 1). In *C. italicus* (Mukhin, 1961) and *M. bivittatus* and *M. femurrubrum* (Bailey and Mukerji, 1976) the authors also recorded a somewhat comparable trend of food consumption rate where it reached the peak at the 6th instar nymphal stage than the early stages. The present result also revealed that in univoltine (*H. banian*) and bivoltine (*A. exaltata*) species 'consumption rate difference' comprehensively ascended from the 4th to 5th instar nymphal stage, where in multivoltine species (*S. pr. prasiniferum* and *O. fuscovittata*) this phenomenon was observed from the 5th to 6th instar nymphal stage (Fig. 1).

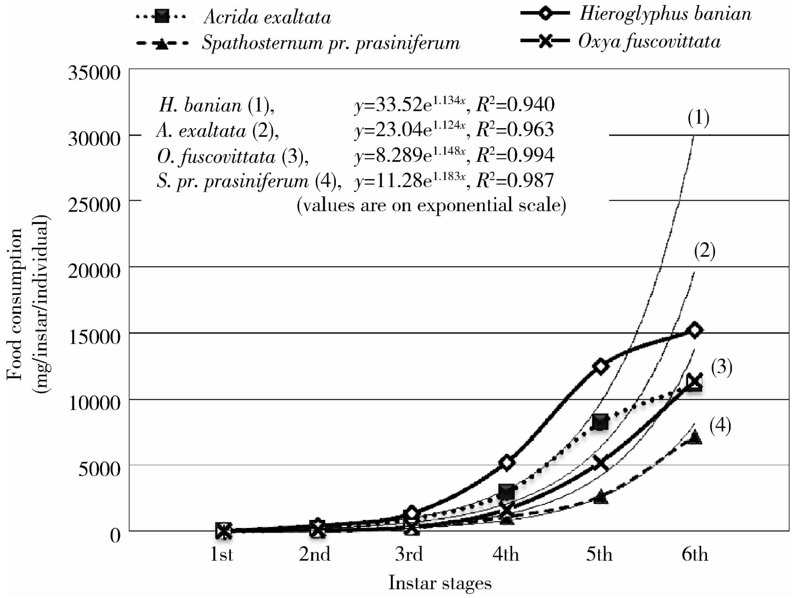

Fig. 1 Food consumption rate of four acridids during all instar nymphal stages

During adult period in comparison of food consumption rate (mg/adult lifespan/individual) among males and females it was found that in all the four species females consumed more than males (Table 2). Similar type of result, where the consumption rate of females was more than that of males, was reported in *E. brachyptera* (Kaufmann, 1965) and *P. nitidus* (White, 1974, 1978), though an opposite phenomenon, where the consumption rate of males was higher than that of females, was reported in *Dociostaurus crucigerus brevicollis* and *Oedipoda coerulescens* (Nagy, 1952) and in *Melanoplus scudderi scudderi* (Gangwere, 1959). In addition, the male-female consumption rate pattern was analyzed by 'independent samples *t*-test' (non-significant if $P<0.05$) and it was found that the uni- (*H. banian*) and bivoltine (*A. exaltata*) species had corresponding but not significantly different consumption rate pattern in both sexes. In the rest two multi-voltine species (*S. pr. prasiniferum* and *O. fuscovittata*) a comparable inclination of parallel but non-significant consumption rates were also noticed (Fig. 2).

Independent samples *t*-test. If $P<0.05$, then the difference is significant, otherwise NS, *i. e.*, non-significant.

Three distinct lifespan stages, *viz.*, a) lifespan of nymphal stage where all instar stages were integrated, b) lifespan of male and c) lifespan of female were framed to analyze the food consumption pattern amongst them. Among these three stages, 'nymphal lifespan' ($R^2=0.67$) and 'female adult-stage lifespan' ($R^2=0.61$) were somewhat significantly different in all species but it was non-significant ($R^2=0.15$) from the 'male adult-stage lifespan' (Fig. 3). In concern of 'total food consumption' (nymphal period consumption plus adult period consumption) of an individual in its 'lifetime' (nymphal period plus adult period), a species consumed higher amount of food during its adult stage than the nymphal period as observed in *M. bivittatus* and *M. femurrubrum* (Bailey and Mukerji, 1976).

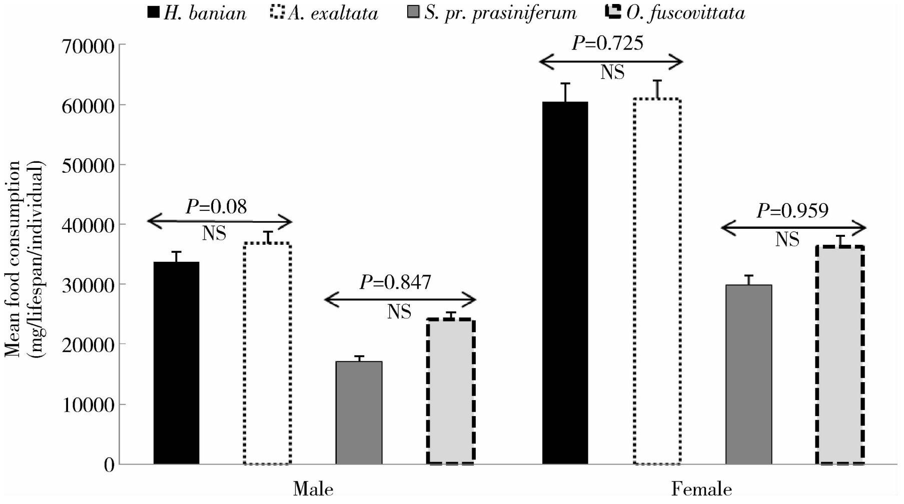

Fig. 2 Mean food consumption rate in adult males ($n = 20$) and females ($n = 20$) of four acridids

Through this observation a notable phenomenon was observed that 'per instar consumption rate' was highly correlated to the 'instar lifespan' and similarly, 'per adult (in either sex) consumption rate' was significantly interrelated to the 'adult lifespan'. For instance, the R^2 values of lifespan (mean days) and food consumption rate (mean mg/lifespan/individual) of each species were 0.96 (*H. banian*), 0.97 (*A. exaltata*), 0.97 (*S. pr. prasiniferum*) and 0.95 (*O. fuscovittata*), respectively (Fig. 4). The result signifies that prolonged 'nymphal period' or 'adult period' ensures higher consumption rate. And this phenomenon was applicable to any instar nymphal stage or to any adult irrespective of sex and species.

Considering the overall findings on total life expantancy (hereafter 'lifetime', nymphal period plus adult lifespan) and food consumption potential in each of the four species either during nymphal (instar stages) or adult period in both sexes, an effort was made in grouping together to those species which have any close proximity either in life-survivability or in feeding potentiality. The result signifies that feeding potential and life-survivability are comparable in long lived species that complete either only one (*i. e.*, univoltine, *H. banian*) or two (*i. e.*, bivoltine, *A. exaltata*) generations per year. On the contrary, the trend is more alike in short lived species which complete more than two generations per year (*i. e.*, multivoltine, *S. pr. prasiniferum* and *O. fuscovittata*) (Fig. 5). It is rather apparent that many long lived species (uni- or bivoltine) have significant irregular life expantancies and that allow them to consume food in erratic nature. This characteristic anomaly in uni- or bivoltine species put together in different cluster of feeding potentiality with short lived 'customary' multivoltine species. A

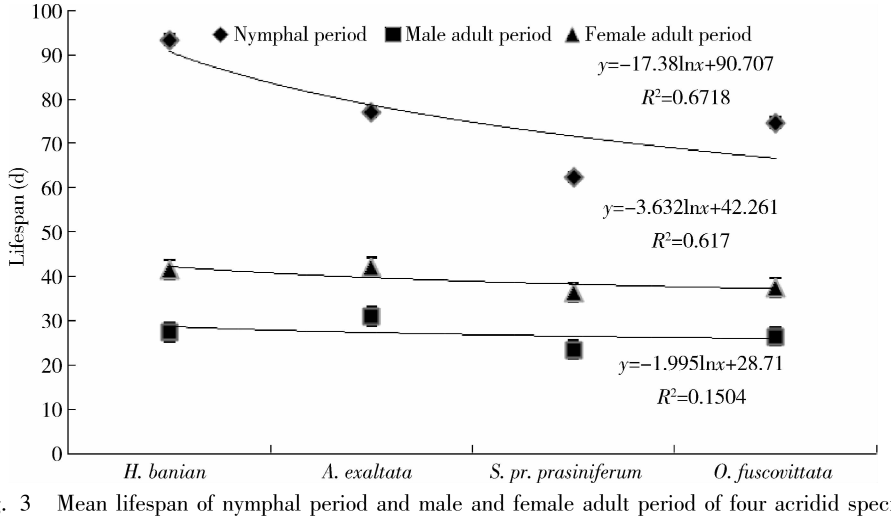

Fig. 3 Mean lifespan of nymphal period and male and female adult period of four acridid species

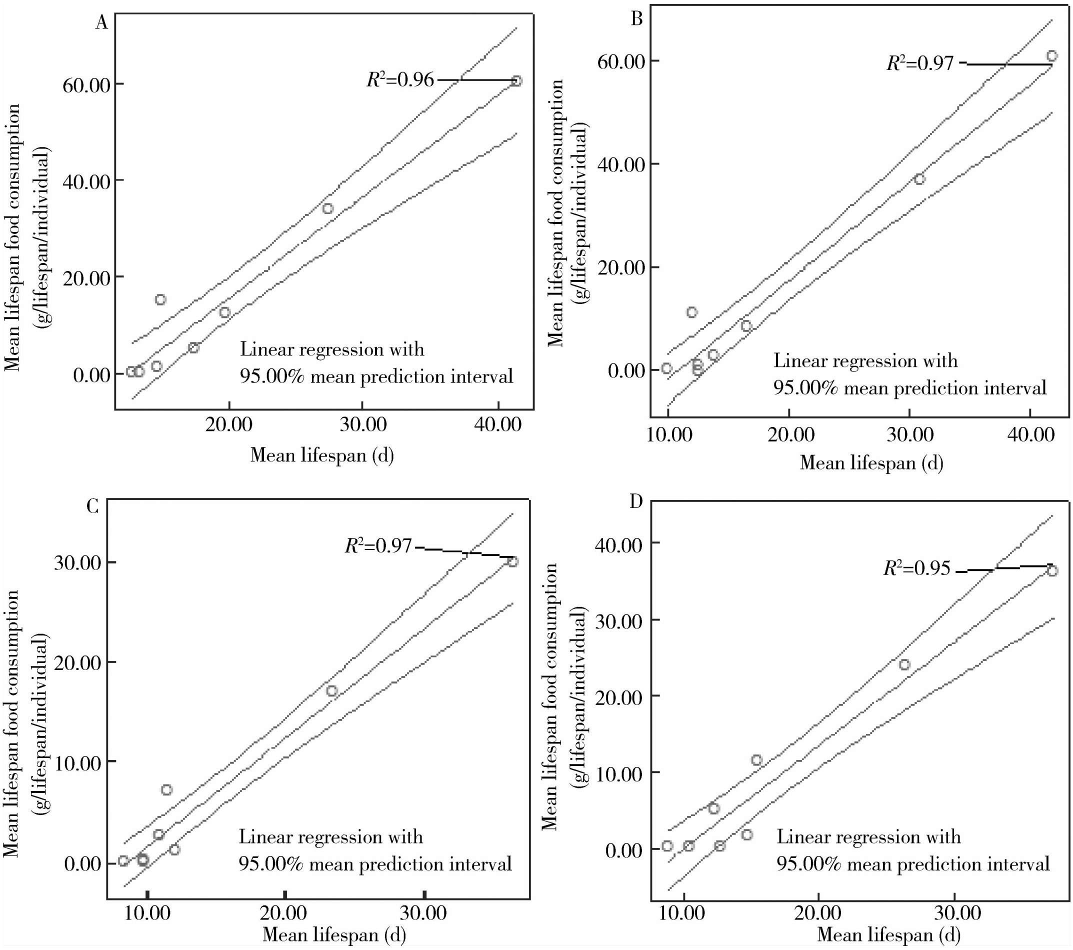

Fig. 4 Regression between mean lifespan and mean lifespan food consumption of each species

A: *Hieroglyphus banian* (R^2 = 0.96); B: *Acrida exaltata* (R^2 = 0.97); C: *Spathosternum prasiniferum prasiniferum* (R^2 = 0.97); D: *Oxya fuscovittata* (R^2 = 0.95).

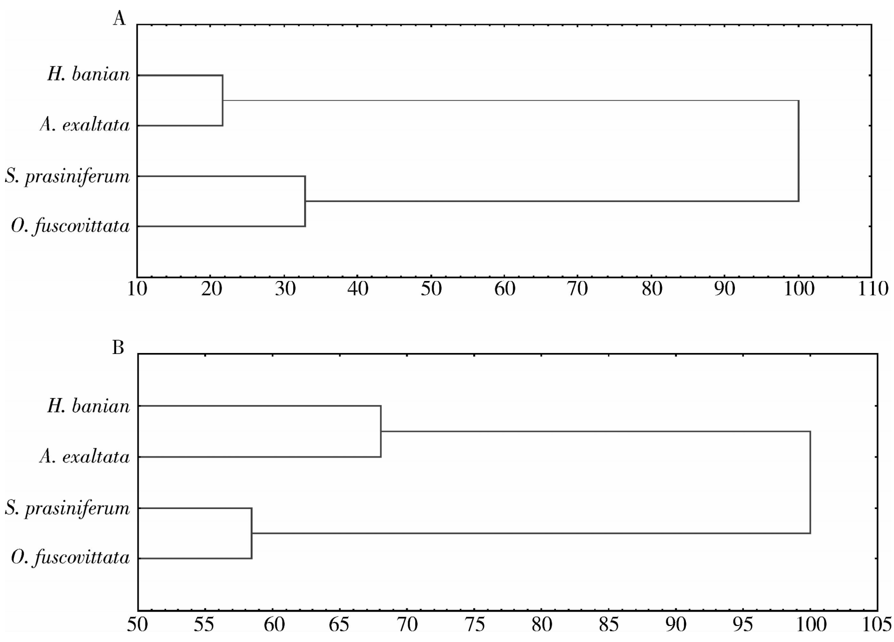

Fig. 5 Dendrograms showing the relationships among the four species with respect to lifetime food consumption (A) and mean lifetime (B)

distinct understanding in this regard requires further studies on other pests of any voltine nature and then some evolutionary consequence might be set forward.

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印度四种蝗科农业害虫的取食量定量测定及据此推测的亲缘关系

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摘要:【目的】害虫的取食潜力反映了其生态学和经济学特性,这些知识有助于扩展其控制措施。能否将害虫物种按亲缘关系的远近进行分组,对它们在发育或成熟期的取食量进行定量排序? 了解不同害虫种类的取食模式有助于这一问题的解答。【方法】对印度 4 种蝗科农业害虫——等岐蔗蝗 *Hieroglyphus banian* (Fab.), 暗翅剑角蝗 *Acrida exaltata* (Walk.), 中华板胸蝗 *Spathosternum prasiniferum prasiniferum* (Walk.) 和 *Oxya fuscovittata* (Mars.)的取食量进行了定量测定,估测了 4 种害虫雌雄各若虫龄期及整个成虫期的每日取食量和总取食量。【结果】基于其多食性特征和存在多种食物来源的情况,所有测试中均只提供最为偏好的寄主植物。在研究的 4 种害虫中,观察到相同的取食率模式,取食率随着若虫龄期的增加而逐步增加。4 种害虫的雌虫取食量均显著高于雄虫,且成虫期害虫的取食量显著高于幼期。各龄若虫和成虫的取食量与对应的若虫或成虫历期明显相关。就整个生活期的取食量和平均存活率而言,暗翅剑角蝗 *A. exaltata* 和中华板胸蝗 *S. pr. prasiniferum* 的亲缘关系比其他两种昆虫略近。就整个生活期的取食量和平均存活率而言,单化性害虫(等岐蔗蝗 *H. banian*)和二化性害虫(暗翅剑角蝗 *A. exaltata*) 比另外两种近缘的多化性害虫(中华板胸蝗 *S. pr. prasiniferum* 和 *O. fuscovittata*)的亲缘关系更近一些。【结论】寿命长的物种(每年可完成 1~2 个世代)在取食潜力方面比寿命短的物种(每年完成 2 代以上的世代)更具有可比性。通过对多个不同化性的害虫物种的研究,使我们在这方面能达到更全面的认识。

关键词: 直翅目; 蝗虫; 取食量; 寿命; 存活; 寄主植物

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